Constellation X
Soft X-ray Telescope
Reference Designs

* Full Shell Optics

*Segmented Optics

Thursday October 14, 1999
FST Meeting

L. Cohen/SAO

* **Areas of Study at SAO**

    * **Non-integral carriers**

        * **Have in hand 3+ full 0.25m shell carriers (SiC, CFRP(2), Alumina)**

        * **Plan to replicate after MSFC's 0.5m shell effort so as not to "endanger" Precison Metrology Mount**

        * **Beryllium segments soon to be delivered**
            * **Plan to replicate after MSFC provides 0.5m mandrel (needs to be "gold stripable")**

    * **Effects of epoxy shrinkage on segmented optics**
        * **Experiments underway**

    * **Glass strength for segments**
        * **Experiments underway**

<u>Todays' discussion will focus on:</u>

* **Reference designs for both full shell and segmented optics**

    * **Integral and non-integral segments for both systems**

Full Shell Optics Reference Design

*** Design is applicable to any full shell material (Ni, SiC, CFRP) but MSFC Ni alloy chosen as baseline material.**

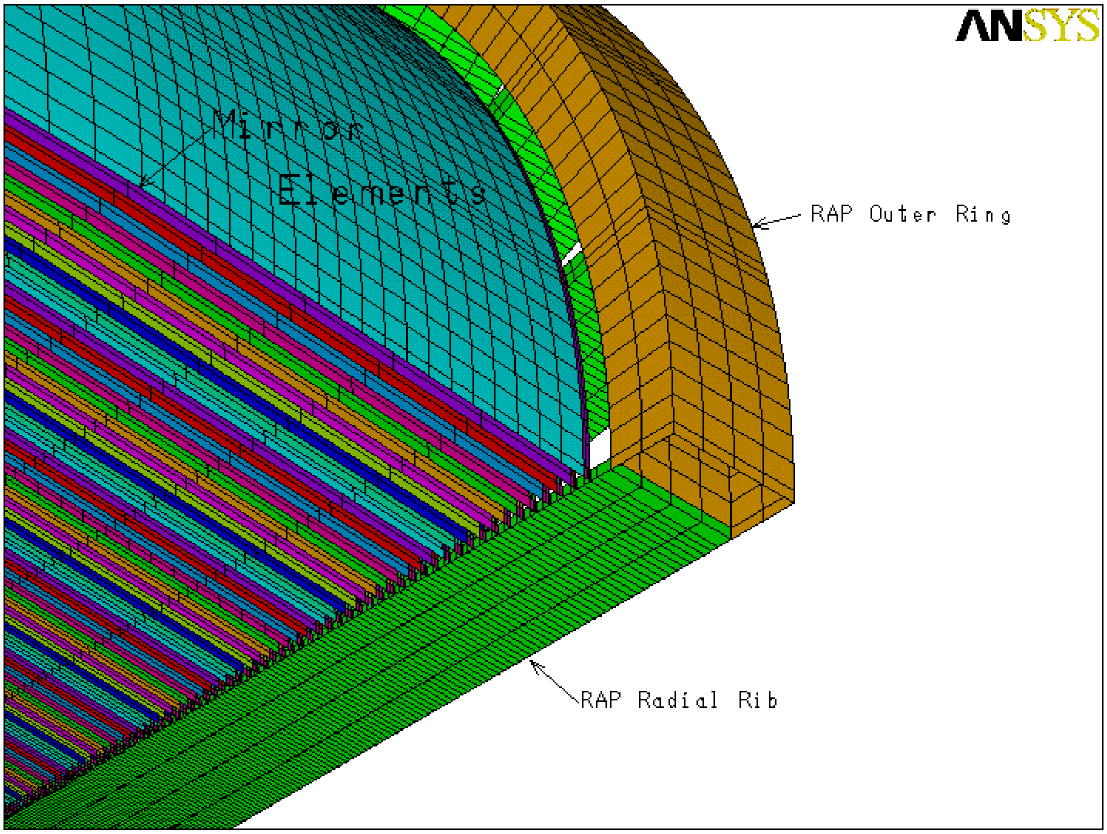
*** Each of the 70 full shells (1 m long, max 1.6m diam) is supported from the hyperboloid end ONLY.**

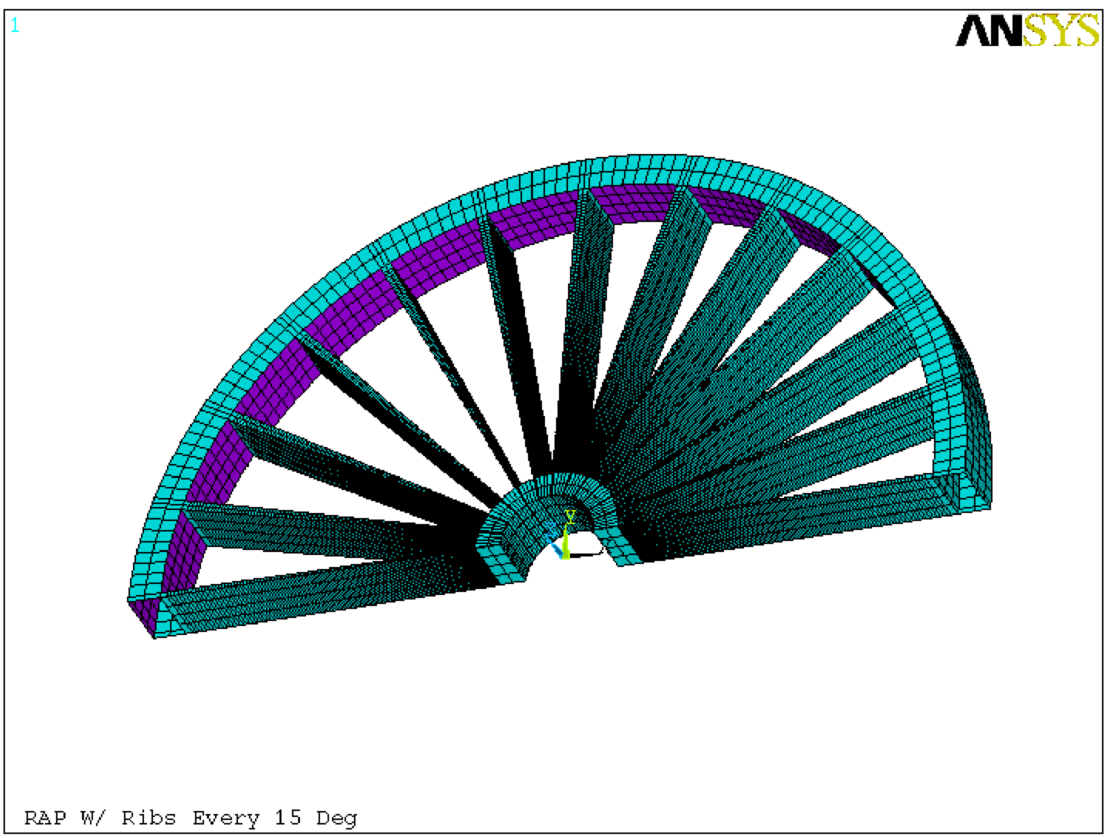
*** 12.5 cm deep "wagon wheel" *R*ear *A*perture *P*late (RAP) structure fabricated from Beralcast, a beryllium/aluminum alloy from Starmet whos' CTE is within 1PPM/C of the Ni alloy.**

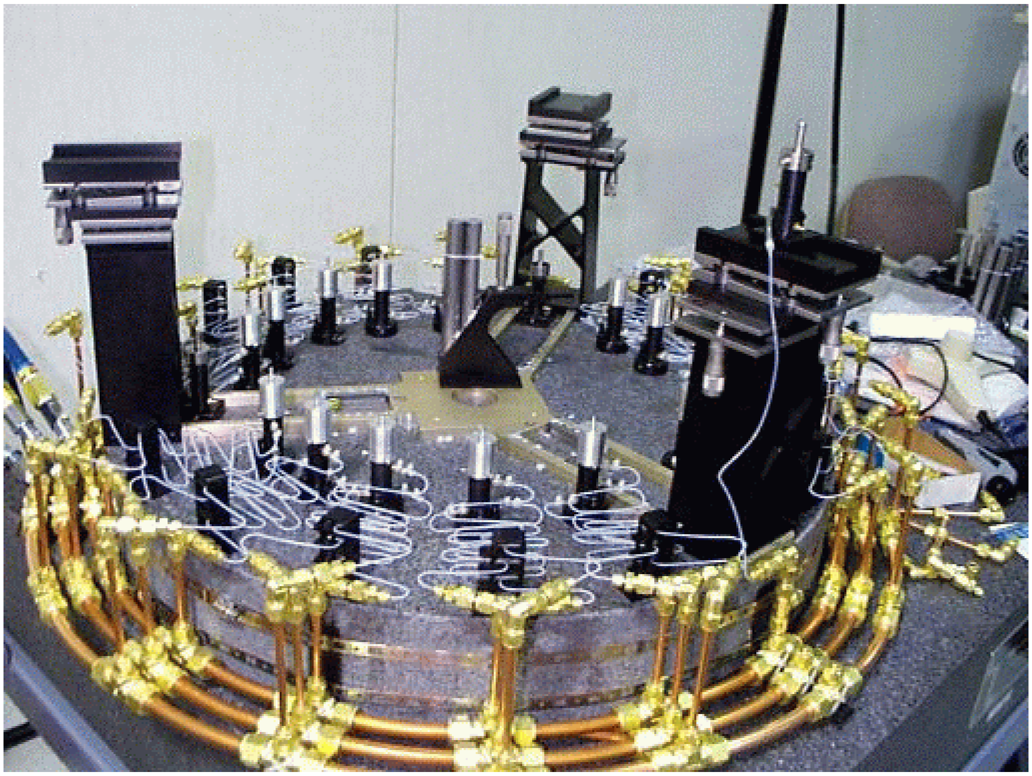
*** Assembly of the optics is performed vertically; largest optic first, smallest optic last. Each optic is held with the SAO designed & built Precision Metrology Mount which is designed to introduce less than 0.5 gram error at each support point.**

*** Each of the 70 optics would be optically aligned with an AXAF type alignment system that was successfully used at E-K and then each optic would be epoxy bonded to the RAP along the radial ribs.**

*** RAP also supports the gratings**


ANSYS
Mirror
Elements
RAP Outer Ring
RAP Radial Rib


1
ANSYS
RAP W/ Ribs Every 15 Deg



* Finite Element Model Of 70 shell system exercised for:

* Uniform Temperature Changes

(shells w/ NO integral end rings)
(per 1PPM/F difference per F)

Table 1

	Half-Power Diameter (arc sec)		
No. Support Points/360 Deg	Shell 1	Shell 27	Shell 70
infinite (unif support)	0.021	0.000	0.000
24	0.379	0.087	0.002
18	0.718	0.268	0.003
12	0.672	0.404	0.032
6	0.268	0.140	0.132
AVG RAD AT P/H JUNC.(inches)	31.496	18.046	6.194
SHELL THICKNESS (inches)	0.0154	0.0092	0.0066

*** Given a thermal error budget of about 2 arc sec (1.5 unif, 1.5 grad), we would need to maintain a uniform temp of < ~5F**

* Launch Type Accelerations

(10 g's equivalent static lateral load)

Table 2

No. Support Points/360 Deg	Shell 1	Shell 27	Shell 70
infinite (unif support)	332. psi	369.	908.
24	6413.	4422.	3560.
18	12360.	7139.	4665.
12	38130.	15970.	6804.
6	337530.	160530.	21570.

*** Given an ultimate strength of the Ni of >100ksi and a F.S. of at least 3, we would need at least 15 ribs (24 deg c/c)**

*** 3-Point Mount of Mirror Assembly Provides an First Frequency > 20 Hz**

Segmented Optics Reference Design

*** Design is applicable to any segmented material (Be, Al, Ni, CFRP) but "slumped glass" chosen as baseline material (Not originally on our list!)**

*** Studies performed to determine number and locations of supports around segment perimeter.**

Table 1- Fundamental Frequency for Various Materials, 30 deg Segment, & Support Spacing

Material	Segment #	30 deg per supt	15 deg per supt	10 deg per supt
TA	1	8.1 Hz	31.8 Hz	65.4 Hz
TA	186	22.1	77.0	123.6
TA	397	66.2	162.6	204.2
EN	1	12.9	31.0	34.6
EN	27	14.8	31.3	31.0
EN	70	22.7	23.7	31.5
SC	1	72.2	133.4	134.0
SC	27	80.9	135.1	137.8
SC	70	94.4	94.9	110.3
BA	1	87.4	146.8	145.8
BA	27	92.7	126.7	146.0
BA	70	112.2	112.5	124.4

Table 2- Fundamental Frequency for Various Materials, 60 deg Segment, & Support Spacing

Material	Segment #	60 deg per supt	30 deg per supt	20 deg per supt	15 deg per supt
TA	1	1.9 Hz	8.2 Hz	18.6 Hz	32.1 Hz
TA	186	5.4	21.5	44.6	83.1
TA	397	18.8	71.6	116.6	162.4
EN	1	4.2	14.7	23.6	32.0
EN	27	6.5	18.7	29.0	34.1
EN	70	19.8	45.4	43.2	50.1
SC	1	27.1	85.6	126.8	144.1
SC	27	39.4	103.2	137.0	137.8
SC	70	106.6	184.8	200.7	211.7
BA	1	103.7	103.7	145.2	155.1
BA	27	123.0	123.0	146.3	144.4
BA	70	169.4	169.4	213.9	222.3

Table 3- Elastic Buckling Load in "g's" per Axis

Material	30 deg segment, 10 deg per support	60 deg segment, 15 deg per support
TA	10.1 X 23.5 Y 241.9 Z	7.0 X 9.3 Y 176.1 Z
EN	5.1 X 13.0 Y 152.0 Z	4.2 X 5.2 Y 101.2 Z

SC	275.4 X 659.2 Y 5031.0 Z	204.5 X 253.7 Y 3387.5 Z

Table 1- Fundamental Frequency for Various Materials, 30 deg Segment & Axial Support Spacing

Material	Segment #	End Pts Only	W/ Mid Point	Third Pts	W/Mid & Qtr Pts
TA	1	8.1 Hz	8.2 Hz	8.2 Hz	NA
TA	186	22.1	22.8	23.0	NA
TA	397	66.2	78.8	81.3	NA
EN	1	12.9	17.4	18.3	18.6 Hz
EN	27	14.8	24.9	28.7	30.2
EN	70	22.7	62.5	90.7	115.4
SC	1	72.2	110.4	119.3	121.9
SC	27	80.9	146.2	181.4	195.4
SC	70	94.4	248.3	452.6	640.2
BA	1	87.4	139.3	152.3	155.8
BA	27	92.7	179.2	228.2	248.6
BA	70	112.2	267.7	479.4	714.3

Table 2- Fundamental Frequency for Various Materials, 60 deg Segment & Axial Support Spacing

Material	Segment #	End Pts Only	W/ Mid Point	Third Pts	W/Mid & Qtr Pts
TA	1	1.9 Hz	1.9 Hz	1.9 Hz	1.9 Hz
TA	186	5.4	5.5	5.5	5.5
TA	397	18.8	19.3	19.3	19.4
EN	1	4.2	4.4	4.5	4.5
EN	27	6.5	7.3	7.5	7.5
EN	70	19.8	34.5	41.9	41.9
SC	1	27.1	29.0	29.3	29.4
SC	27	39.4	47.3	48.8	49.2
SC	70	106.6	190.3	252.1	285.5
BA	1	34.1	37.1	37.5	37.6
BA	27	48.3	60.1	62.3	63.0
BA	70	121.2	228.4	309.6	358.2

Table 3- 60 deg Segment w/ Both Axial (3) and Azimuthal (3/4) Supports

Material	Segment #	Axial (3); Azimuthal (3)	Axial (3); Azimuthal (4)
TA	1	8.2 Hz	18.9 Hz
TA	186	23.0	52.7
TA	397	82.3	190.8
EN	1	18.1	37.2
EN	27	27.5	44.7
EN	70	77.5	88.0
SC	1	117.1	209.7
SC	27	164.1	235.1
SC	70	356.7	352.0
BA	1	148.6	244.7
BA	27	192.7	268.5

BA	70	394.5	393.9

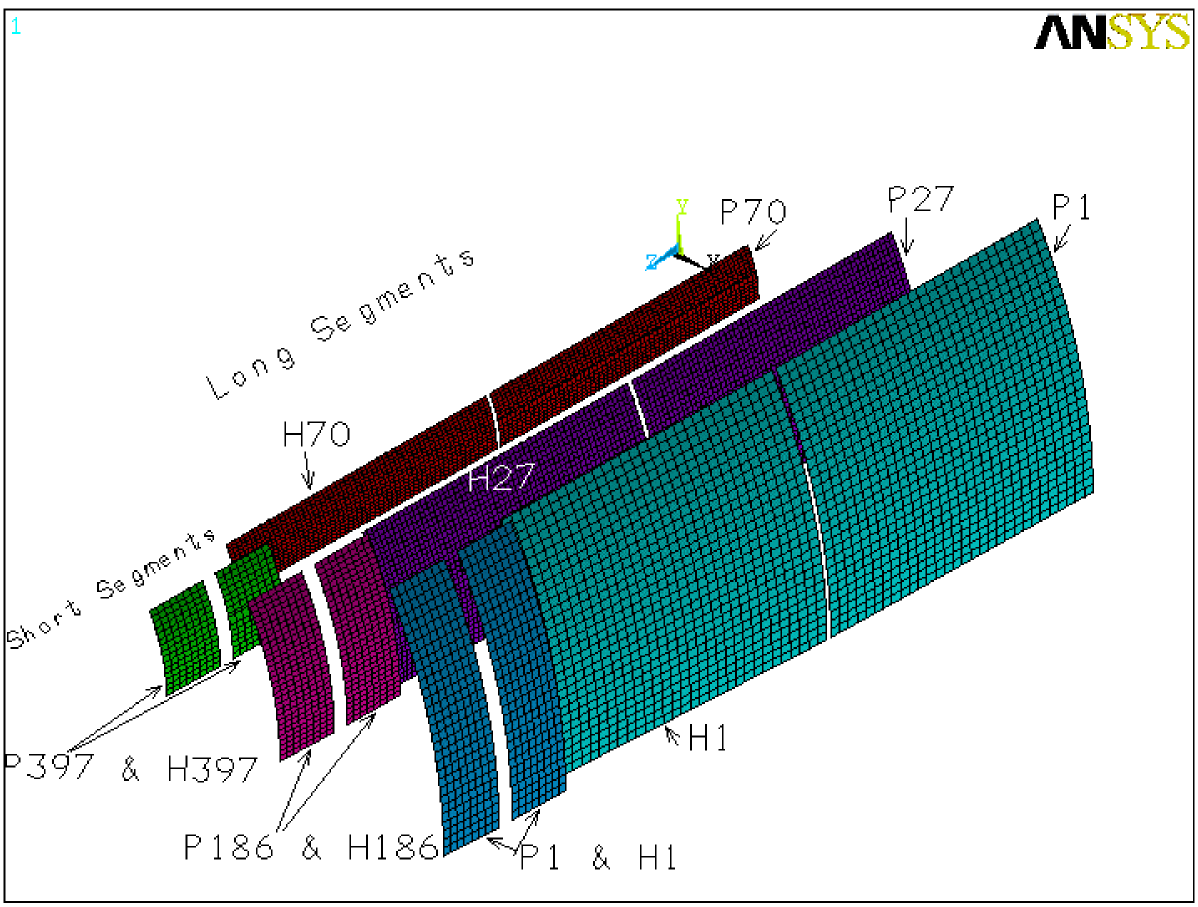
Table 4- Elastic Buckling Load in "g's" per Axis

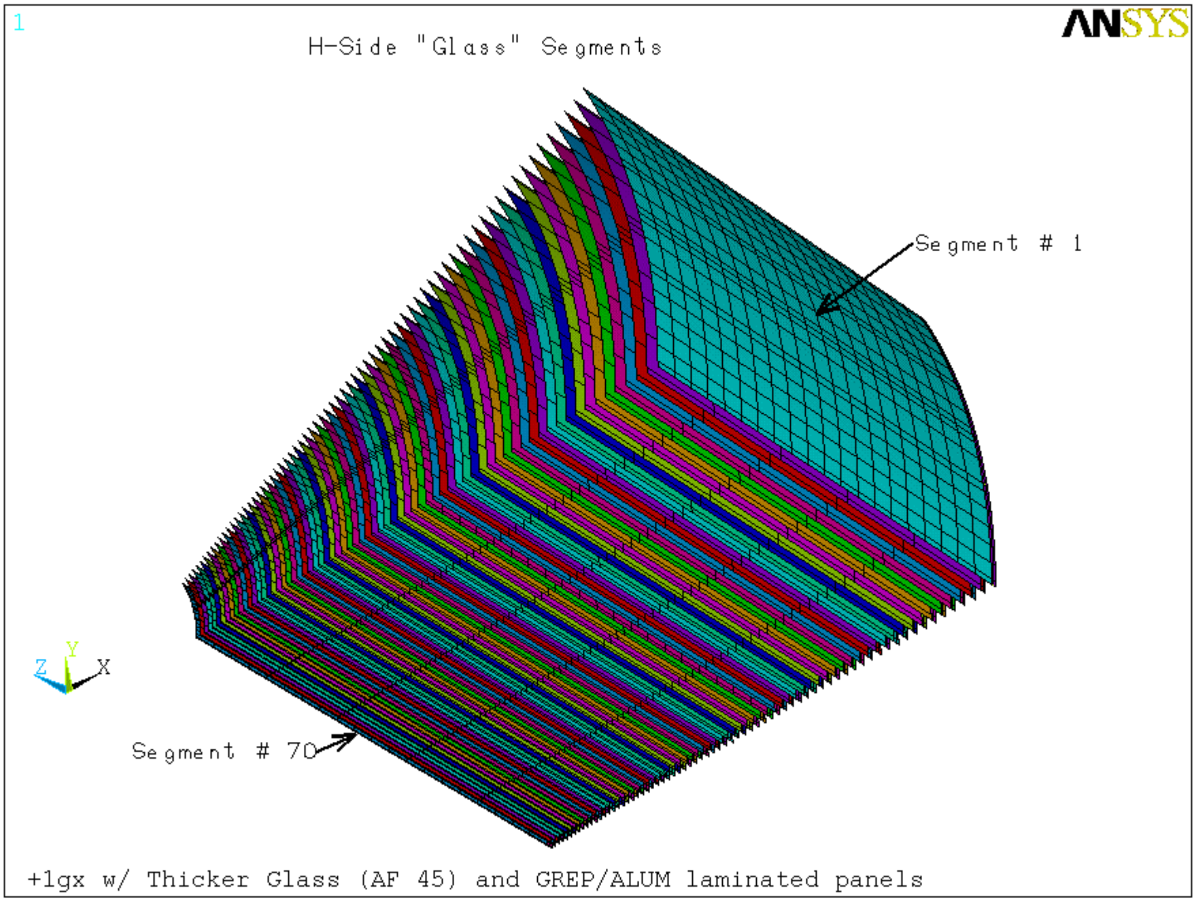
Material	Axial (3), Azimuthal (0)	Axial (5), Azimuthal (0)	Axial (5), Azimuthal (3)
TA	0.4/0.7/3.3	0.4/0.7/3.4	1.9/2.8/31.6
EN	2.3/3.7/24.1	2.4/3.8/30.7	9.8/14.3/138.9
SC	98.6/158.5/928.2	101.7/164.1/1302.3	414.6/589.0/3534.6

Note: The 3 (5) axial supports points are equally spaced (each corner plus midpoint (or quarter-point)).

TA=Thin Aluminum foil; EN=Electroformed Nickel; SC=Silicon carbide
BA=Beryllium/Aluminum alloy

* **Conclusion--All but the thinnest aluminum or nickel will provide enough stiffness and will not buckle**





*** Each *MODULE* is composed of 70 mirror segments, nominally 30 deg per segment and 0.5m long (P/H) .**

*** Each segment is supported by 4 support points at each end.**

***A *<u>P</u>*recision *<u>A</u>*ssembly *<u>S</u>*tation (PAS) is used to put each segment exactly where it should go (to within <1um positional error)**

*** The PAS is assembled around the flight structure (Al/CFRP composite) and is removed after all 70 segments have been aligned and epoxy bonded.**

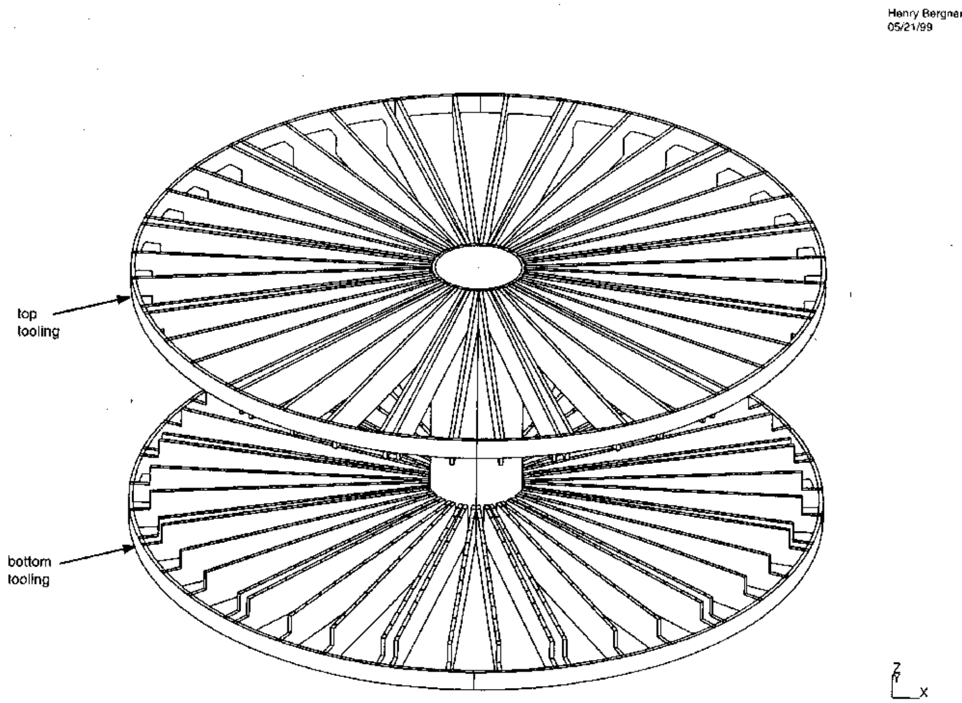
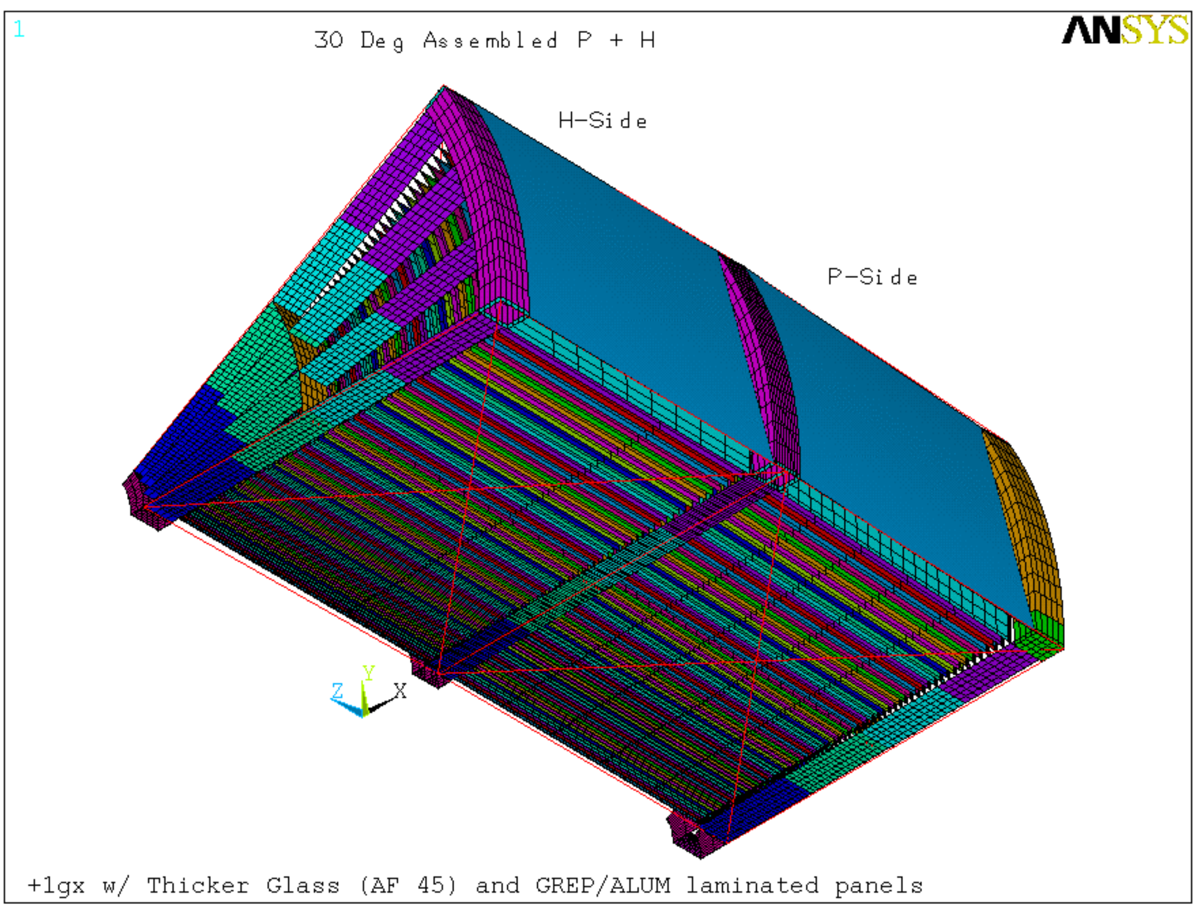
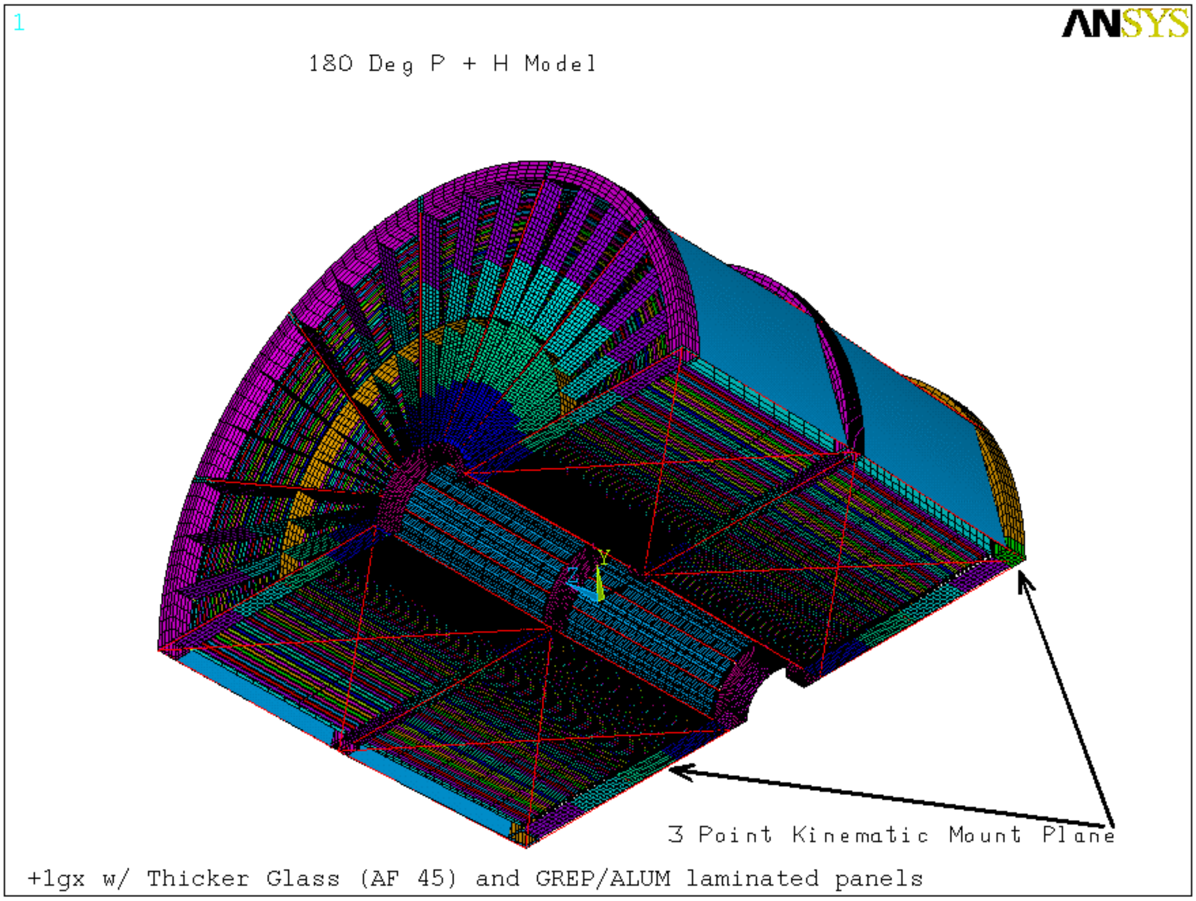


Figure 3. Top, Bottom, Center Tooling Assembly





*** The same 3 point type mount as used for the full shell system was assumed here..(provides a fundamental frequency > 40 hz)**

*** Equivalent lateral launch loads of 10 g's causes glass stresses ~ 15 ksi. Glass strength tests are now underway at GSFC. Data available soon !**

D263(0.4mm) ~ slumped ~20ksi , non-slumped ~ 39 ksi
D263(0.3mm) ~ tbd , non-slumped ~ 45 ksi
AF45(0.3mm) ~ tbd , non-slumped ~ 53ksi
(VALUES ARE AVERAGE VALUES!)

* Uniform Temperature Changes

Table 1-Half-Power Diam due to +1F dT for a 0.3PPM dCTE between segments and structure

Thick Glass	Half-Power-Diameter(arc sec)
Shell 1	2.6
Shell 27	0.4
Shell 70	0.6
Thin Glass	
Shell 1	1.6
Shell 27	0.4
Shell 70	1.0

*** Need to match CTE better in order to allow 5-10F changes.**

* Vertical Assembly of Segments Is Required to Minimize Assembly Errors

Table 1-Half-Cone Angles of Select Mirror Segments

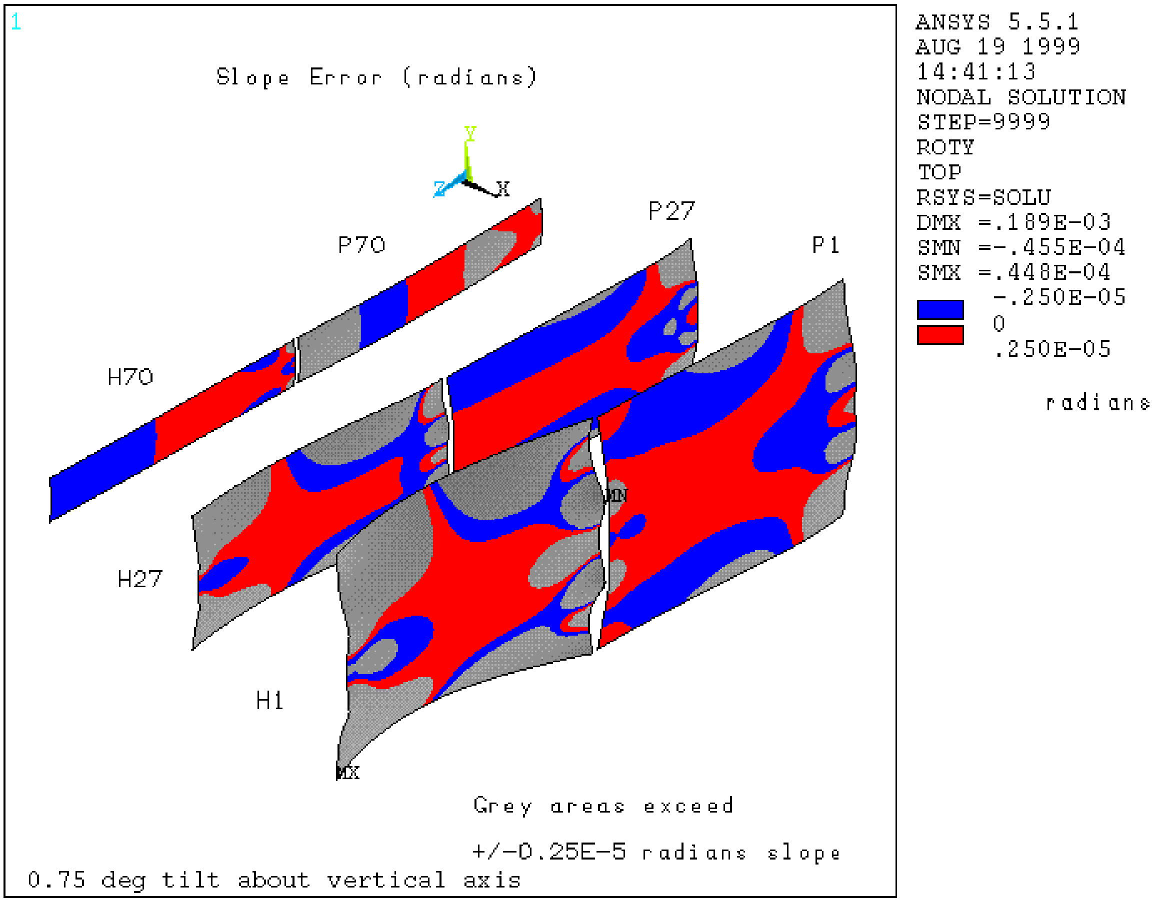
Mirror	P1	H1	P27	H27	P70	H70
Cone Angle(deg)	1.14	3.44	0.68	2.03	0.22	0.67

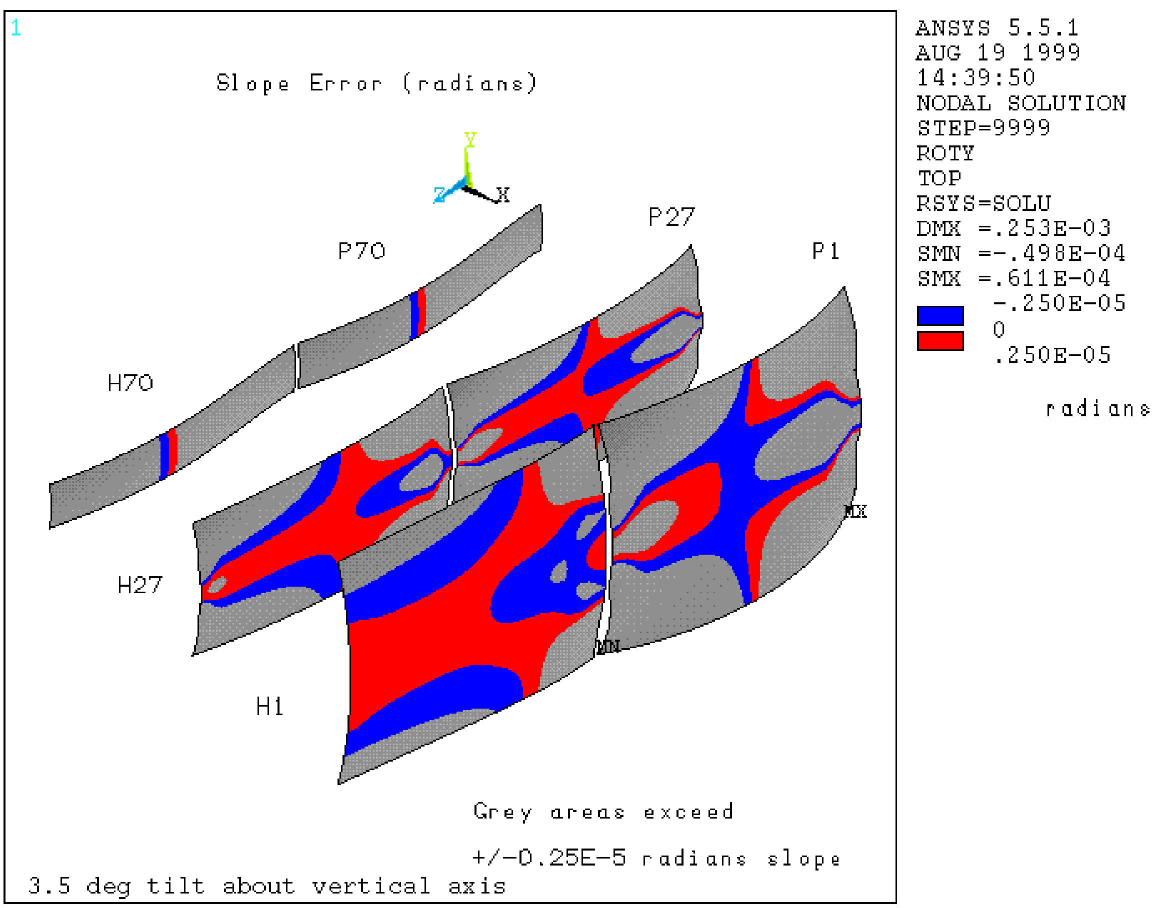
*** Segments must be epoxy bonded in groups**

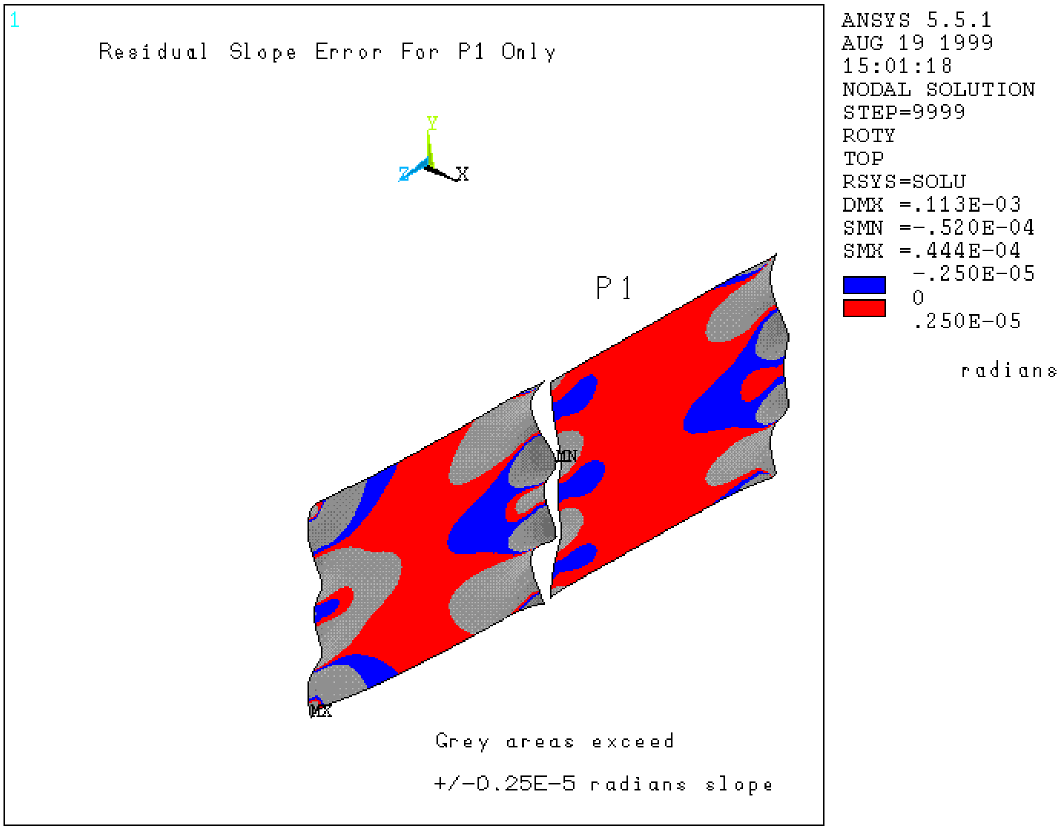
*** Each group would be "tilted" so that its average "azimuth" would be vertical.**

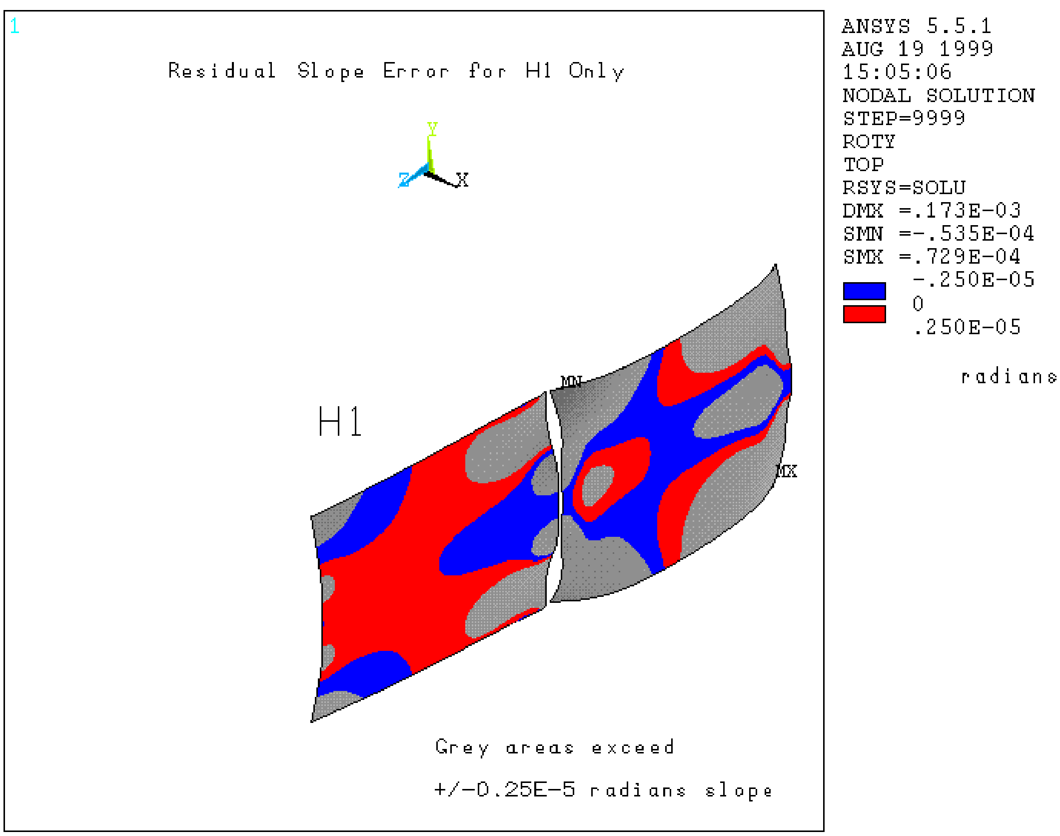
*** Approx 2-3 groups would be needed for the P assembly and about 3 times that**

for the H assembly.






1
Residual Slope Error For P1 Only
P1
MN
MX
Grey areas exceed
+/-0.25E-5 radians slope
ANSYS 5.5.1
AUG 19 1999
15:01:18
NODAL SOLUTION
STEP=9999
ROTY
TOP
RSYS=SOLU
DMX =.113E-03
SMN =-.520E-04
SMX =.444E-04
-.250E-05
0
.250E-05
radians


1
Residual Slope Error for H1 Only
H1
MN
MX
Grey areas exceed
+/-0.25E-5 radians slope
ANSYS 5.5.1
AUG 19 1999
15:05:06
NODAL SOLUTION
STEP=9999
ROTY
TOP
RSYS=SOLU
DMX =.173E-03
SMN =-.535E-04
SMX =.729E-04
-.250E-05
0
.250E-05
radians

* Conclusions

*** Full shell Ni mirror reference design seems feasible**

*** Other materials will probably also work**

*** Segmented glass mirror reference design *<u>may</u>* be "overstressed"**

*** Will determine what changes are required to alleviate stress**

*** Other segmented mirror materials (such as beryllium) are probably OK**